Ping-Pong Altimetry Lab

Objective:
The learner will understand, through a hands-on experience, the basic concepts behind the use and working of a laser altimeter for the study of solar system topography.

Outcomes:

- Students will plot and graph data they have collected using a hands-on version of laser altimetry.
- Students will gain an understanding of the use of laser altimetry in the study of planetary topography.

Introduction:
January 10, 1999, the satellite NEAR begins an orbit of 433 Eros, which makes it the first spacecraft to orbit, and study, an asteroid. One of the instruments aboard the satellite is a laser altimeter. The laser will be used to take topographical measurements of the surface of 433 Eros. With this data, topographical maps and 3 dimensional models will be created. This activity will introduce you to the concept of laser altimetry and how the data is used in order to create maps and model solar system bodies.

Materials:
       Ping-pong ball
       wooden blocks of various sizes
       masking tape - 2 pieces @ 10 cm each (optional)
       meter stick
       stop watch
       graph paper (enough for 3 graphs per group)
       pen/pencil

Procedure:
This activity requires at least two people per group. Three people per group would be the optimum. The jobs can be rotated if group members so desire. Read through the whole activity before beginning.
STEP ONE:

1. Choose a spot on a wall 2.2 m or higher from the floor, and place one 10 cm length of tape on the wall, at that height, parallel to the floor. (You may need a chair.)
2. Holding the ball next to the tape on the wall, between your first finger and thumb, drop it and watch to see how high it bounces back up. Mark that spot on the wall with your finger. It is best to do this step two or three times to determine the highest point of return. (Using the mortar lines on cinder block walls will work well, too. Be sure to use the same two lines throughout this whole activity.)
3. Measure 45 cm toward the floor and mark this spot with the second piece of tape. This will be the constant for measuring the time for the ping-pong ball's period.

4. Measure the distance from the first piece of tape (or mortar line) to the floor and back up to the second tape line. Record this on your data sheet. This distance will be used to create a baseline for all other measurements, so be as precise as you can.
5. As in number two, one partner should hold the ping-pong ball next to the higher piece of tape, between the first finger and thumb, and approximately one inch from the wall.
6. One partner should have a stopwatch and have his/her eyes level with the second piece of tape. A third partner, if available should be recording the results of each ball drop using the attached data sheet or one that your group makes up for itself. *Note: A spreadsheet would work well for recording and calculating this data.*
7. Drop the ball, and as you do say, "Go." The timer starts the stopwatch on "Go."
8. The timer will stop the watch when the ball rebounds and reaches the lower line. (His/her eyes should be level with the lower piece of tape. The time should be stopped as soon as any part of the ball touches any part of the line.) Record the time on the data sheet. Repeat this step four more times.
9. Calculate the velocities (V=D/T). After finding the velocity for each of the trials, find the average velocity of the ping-pong ball. This average will be used later in this lab. It will be your baseline for comparing data.

STEP TWO:
Now that you have found the velocity of the ping-pong ball, you will use this information to plot the topography along a line of latitude of an asteroid. You will be creating your own asteroid terrain on the floor against the wall where you just did Step One.

1. Create the topography model of *your* asteroid, along the wall where you did Step One. In order to do this you need to place the wooden blocks *against* the wall in a line about 6-8 feet long. Be sure that you build in some hills, mountains, valleys, etc. (See Figure A)
2. If you used tape in Step One instead of the mortar lines, you will probably want to add new lengths of tape to the originals that extend over the entire length of your topographical model. Be sure that the new lines remain parallel to the floor so that the heights don't change along the length of the model.
3. Starting at the beginning of the top piece of tape, place a mark every 20cm. The bottom piece does not need to be marked.
4. Again, starting at first interval mark you made at the beginning of the tape, you will drop the ping-pong ball as you did in Step One, and record the time in Data Table II. Drop the ball and record the results two more times. Be sure to be as accurate as you can with the timing.
5. Repeat number four for each of the interval marks you placed on the wall.
6. Find the average time for each of the intervals and record it on the data table.

STEP THREE: PLOTTING AND GRAPHING THE DATA:
You will now plot the data for the average times and create graphs of the altimetry

readings for your topographic model. The graphs will use different intervals between readings, so that you can compare the preciseness of different levels of accuracy (called spatial resolution).

Graph 1

1. Plot the average time for every 60cm interval. (0cm, 60cm, 120cm, etc.)
2. Connect the points with a smooth line.
3. Label the graph appropriately.

Graph 2

1. Plot the average time for every 40cm interval.
2. Connect the points with a smooth line.
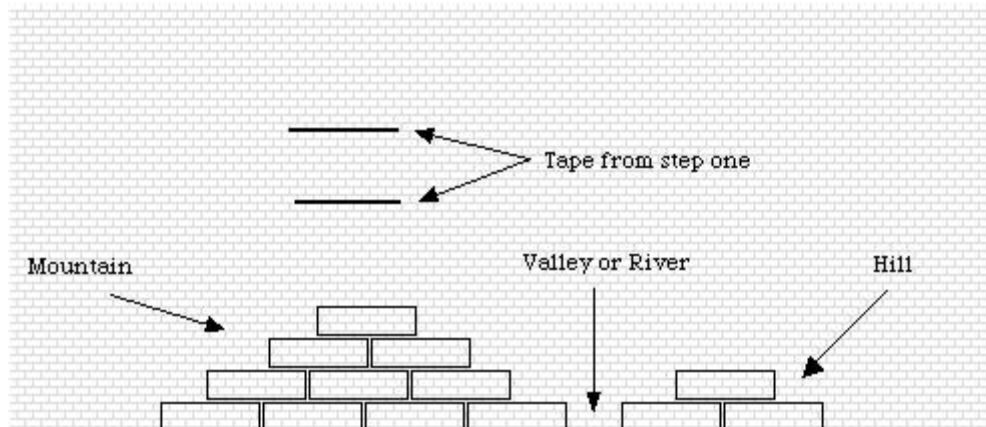3. Label the graph appropriately.

Graph 3

1. Plot the average time for every 20cm interval.
2. Connect the points with a smooth line.
3. Label the graph appropriately.

PING-PONG ALTIMETER
Data Table I

Drop	Distance ball traveled	Time (seconds)	Velocity (distance/time)
1			
2			
3			
4			
5			
		Average Velocity	_____

Tape from step one

Mountain

Valley or River

Hill

PING-PONG ALTIMETER
Data Table II

Interval	Trial 1	Trial 2	Trial 3	Average Time (sec)	Distance Ball Traveled (cm)
0cm					
20cm					
40cm					
60cm					
80cm					
100cm					
120cm					
140cm					
160cm					
180cm					
200cm					
220cm					
240cm					
260cm					
280cm					
300cm					

PING-PONG ALTIMETER
Data Table III

°R Interval	Original Distance Ball Traveled (From Data Table One) {D1}	Distance Ball Traveled (cm) {D2}	Altitude (cm) {D1-D2= Altitude}
0cm			
20cm			
40cm			
60cm			
80cm			
100cm			
120cm			
140cm			
160cm			
180cm			
200cm			
220cm			
240cm			
260cm			
280cm			
300cm			

Use your graphs and data to answer the remaining questions.

Why is it important to keep the distance between each altimeter measurement consistent?

How could we make the topographical profile more accurate?

What does the graph look like in comparison to your model (i.e.. the same, inverted, etc.)?

Which looks more like the model, the graph you generated from the shorter or longer distances between readings (intervals)?

What will you have to do to the data to make the graph look right-side up?

The Laser Rangefinder aboard NEAR sends out a laser beam and "catches" it as it returns from being reflected by the surface of 433 Eros. The instrument records how long it takes the beam to reach the surface and bounce back up. The scientists know how *fast* the beam is traveling; therefore, they can calculate how *far* it traveled. By measuring this time and multiplying by the velocity of the beam, they calculate how far the laser has traveled. They must then divide the distance the beam traveled in half.

Why did you not divide in half to find the distance to the object in *your* topography model?

Next, the scientist must compare this distance to a "baseline" distance we will call zero. On Earth, we might use sea level as the baseline. Another way to set the baselines is to start at the center of the planetary body being studied and draw a perfect circle as close to the surface of the body as possible. Using this baseline, the altitude compared to zero can be calculated and graphed. (Here, on Earth, we often say that some point is a certain number of feet above of below sea level.)

Why do we not use the term "Sea level" for Mars and other planets?

You will now calculate the altitude of the points along your model. To do this subtract the distance the ball traveled, at each interval (from Data Table II) from the distance the ball traveled in Step One (column B, Data Table I). The number you come up with will be zero or greater. Use Data Table III to do your calculations. {The number in column B in this table should be the same for every interval. Remember, it was the baseline altitude and does not change.}